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METAPHORS FOR THE EFFECTS OF WEAK, SEQUENTIALLY COMPLEX MAGNETIC FIELDS[1]

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Summary.—Metaphors to explain the effects of weak, complex magnetic fields upon the neuromatrices of organisms are suggested. The ratio of the amplitude of the time-varying components to steady-state components for complex magnetic field for effective biological responses may display Weber values that are similar to those for the electrical activity of the brain, the detection of changes in sound pressure by the ear and for more classical sensory thresholds. The nonlinear, suprathreshold characteristic of weak magnetic field effects would be similar to the effective narrow windows of concentrations of ligands values for receptor subtypes with different affinities. Signals composed of trains of between 100 and 1000 successive, fast (1 to 3 msec.) transients, which would contain the most biological information, would require low amplitudes to which the substrates could respond and with which the neuromatrix could resonate.

The concept that qualitatively different phenomena such as information emerge within and are constrained by a specific range of values that constitute the ratio of intensities of time-varying to the steady-state energies is found within all sciences. In classical psychology Weber's law indicates that the ratio of the magnitude of the changing stimulus relative to the amplitude of the stable reference stimulus displays a discrete value (constant) in order for information (detection) to be discerned. The detection of information within and the effects upon organisms by weak, complex magnetic fields have been frequently ignored because of the implicit assumption that weak time-varying intensities are masked by stronger steady-state intensities or higher frequency, man-made sources.

The amplitude of daily geomagnetic variation within the primary temporal domain between 1 mHz (period of 16 min.) and 1 Hz are normally within the range of 10 nT to 100 nT (nanoTesla), depending upon latitude; the primary modulators of this range are sudden changes in the velocity and density of the solar wind (due to flares) and the earth's penetration of sectors of the solar interplanetary magnetic field. Assuming a local steady-state field value on the order of 50,000 nT (0.5 gauss), the ratio of variability is between 0.02% and 0.2%. These ratios have been considered too small to be discernable by or biologically relevant to complex neural systems such as the human brain even though they are within the ranges of the Weber constants for other sensory modalities.

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However, the physical limits of detection of these fluctuations would be analogous to discriminating complex sounds. Human organisms are immersed within a gaseous (atmospheric) field. The stead-state intensity of the atmosphere is about 100 kPa while the threshold for human hearing involves time-varying compressions or rarefactions within this gaseous field of about 10 microPa. Consequently, the propagation of information through normal talking, within the range of 50 db to 70 db, would involve a range of ratios between .001% and .1%. One would presume that detection of the rich amount of information within this acoustic energy would not be dismissed because the ratio of the time-varying (sound waves) to the baseline (atmospheric pressure) was too small.

Considering the near infinite combinations of temporal variations in intensity of mechanical or electromagnetic fields, one would expect the cells that transform these energies into patterns of action potentials within the neuromatrix to have a limited capacity to represent these stimuli. For sound this range is primarily between 100 Hz and 10 kHz and is defined by the physical constraints of the sensor. Propagating acoustic fields above or below this range are not as effective within normal amplitudes (Woodworth & Schlosberg, 1954). This finite capacity is described as "band width" and often presumes symmetrical temporal variations (sine or square waves). Although atypical shapes with variable interpulse times within an envelope whose interval of delivery can also vary (such as burst firing) would be included (Persinger, Richards, & Koren, 1997), the transformational implications of these nonlinear shapes within brain space have not been pursued extensively.

Most of the power within the daily variations (10 to 100 nT) that constitute global geomagnetic activity is within the mHz range. Fundamental peak-to-peak variations are kiloseconds to decaseconds while higher frequency bands of ripples within the 1 Hz to 100 Hz range are superimposed with secondary peak-to-trough amplitudes of about 0.1% to 1%. Consequently, if these fundamental and secondary components are central for the influence of geomagnetic activity upon the neuromatrix of an organism, then it would require representational systems with these properties. Large populations of cells with the capacity for steady potential shifts upon which asymmetric burst firing occurs (Dichter & Ayala, 1987) such as some limbic networks would be candidates. Symmetrical frequencies above this range and without the correlative shift in the "steady-state" components, even with amplitudes 100 times higher (such as 60-Hz sine waves from man-made power sources) would not be as effective.

If the concept of resonance is applicable to the interaction between geomagnetic activity and the neuromatrix, then optimal congruence should occur between patterns and intensities that are similar in both. It may be

relevant that the amplitudes of the range of electroencephalographic frequencies (1 Hz to 40 Hz) by which we generally infer levels of consciousness is in the order of 10 to 100 microV/m and are superimposed upon a steady-state neural field of about 10 mV/m; the ratio is between 0.1% and 1% and can be considered analogous to the relationship, although within a different time-frame (mHz vs Hz), between geomagnetic activity and the earth's steady-state magnetic field. The concept of congruence would predict that the information contained within the ratios of the amplitudes of geomagnetic activity to the intensity of the steady-state field would be most easily represented within the neural systems that reflect the ratios of time-varying to steady-state fields. Candidates are the thalamic pacemaker cells which are modulated by aggregates of slower (3-min. to 5-min.) oscillating glial cells.

The final metaphor whereby one may describe the effects of weak magnetic field effects is that as the complexity of the temporal morphology ("wave structure") of the magnetic field increases and the biological relevance of the information it contains is enhanced, smaller energies are required to elicit changes within resonant (reluctance-matched) portions of the neuromatrix. The neuronal aggregates that constitute the representational requirements for these sequentially complex fields would be expected to operate within very narrow ranges of intensities or energies. Larger, symmetrical (sine wave) low-frequency excursions would require large chunks of neuronal time whose induced currents would synchronize the discharges of most of the susceptible elements of the aggregate and hence decrease the degrees of freedom and the computational rate within the aggregate.

The concept of sensitivity or window effect to a narrow range of amplitudes with complex structures is analogous to the concept of differential affinities for subtypes of receptors for neurotransmitters. The activation of high-affinity receptors occurs within a specific range of concentrations of the ligand. Below that threshold, there is no response. Concentrations of ligand above the optimal increment either stimulate other receptor subtypes for the same ligand, that usually generate biochemical changes resulting in opposing and often cancelling responses, or saturate the high affinity receptor and encourage down-regulation of its density. In both situations concentrations that exceed the optimal window are less effective or not effective.

Applied magnetic fields whose intensities exceed the limits of these narrow-range circuits would quickly overload their capacity and dissipate their functions. However, unlike electronic circuits which could be irreparably destroyed, neuroelectrical pathways could have the capacity, after a latency on the order of 10 days (range of time required for receptor proteins to be synthesized *de novo*), to be reconstituted given there has been no change in the gene expressions.

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